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ABSTRACT

This digest reviews a range of research studies that examine the possible causal linkages between school buildings and student outcomes and behavior, and it presents findings in support of the theory that facilities make a difference and also presents findings in areas where research to date is relatively inconclusive. The report also examines studies concerning the relationship between student outcomes and behavior based on the overall building condition as well as the influence of individual building elements. Also discussed are design factors that can influence learning outcomes and behavior. A list of Web sites for additional information is included. (Contains 31 endnotes.) (GR)

Schooling Issues Digest

Building Better Outcomes:

The Impact of School Infrastructure on Student Outcomes and Behaviour

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SCHOOLING ISSUES DIGEST

Building Better Outcomes:

The Impact of School Infrastructure on Student Outcomes and Behaviour

Introduction

The Commonwealth Department of Education, Training and Youth Affairs (DETYA) is publishing a series of brief reports titled 'Schooling Issues Digests' which summarise existing research material on selected topics relevant to schooling in Australia. The purpose of these Digests is to provide status reports on the results of recent international and national research on selected topics, in a non-technical, easy to read format, which brings together and demystifies complicated research and statistical data. Contact Irene Kaspar on (02) 6240 5444 or email address irene.kaspar@detya.gov.au for more information on this series. For further information on this particular Digest, contact Jason Coutts on (02) 6240 7962 or email address jason.coutts@detya.gov.au

The author of this Digest is Mr Kenn Fisher. Mr Fisher is currently Director of Rubida Research and was Head of the OECD Programme on Educational Building (PEB) in 1997–98.

Overview of this Digest

This Digest reviews a range of research studies which examine the possible causal linkages between building design and student outcomes. It sets out those findings that are agreed and those areas where research to date is relatively inconclusive.

Considerable rigorous and academically sound empirical quantitative research work has been carried out in the United States. However, the sample sizes vary between studies as do the levels of correlation between achievement and building conditions which suggests that more studies need to be carried out in this field to fully validate the findings. Conversely, in Europe, the findings appear to be based more on qualitative studies derived from social science methodology. In these cases direct causality is more difficult to establish, although newer narrative and ethnographic research approaches are being increasingly pursued. These qualitative studies have provided a deeper analysis and understanding of the more classical scientifically based quantitative findings.

Taking the above factors into account, the research indicates that

- student academic achievement improves with improved building condition;
- individual factors, such as lighting levels, air quality and temperature and acoustics, have an effect on student behaviour and outcomes, although there is limited quantitative evidence available on some of these factors; and
- new and emerging trends in school building planning and design and their impact on student outcomes and behaviour have yet to be evaluated using a rigorous research methodology.

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Measuring Building Condition, Student Outcomes and Student Behaviour

Criteria for Assessing Building Condition and Design

Studies carried out on the impact of the age of school buildings generally identify three categories representative of school building age: *non-modernised, modernised, and new*. In addition, over the past 20 years it has consistently been shown that there are 27 critical building elements whose design features, condition and levels of maintenance all influence learning outcomes and student behaviour.[1] For the purposes of conducting controlled studies, these 27 elements have been aggregated into two categories: *structural* and *cosmetic* factors (see table below). Of the 27 items, seven were found to have a major impact and are examined in more detail in this Digest.

To ensure comparability between the condition of schools, the Commonwealth Assessment of Physical Environment (CAPE)[2] was developed in the United States. Teachers self-assess the condition of the elements, scoring them as substandard, standard or above standard. A similar approach, the School Environment Assessment Method (SEAM), is used in the United Kingdom.

Measuring Student Outcomes

Many of the research studies use standardised assessment for literacy and numeracy measurement. United States building condition and student performance studies are based on a range of student assessment methods, including the Test of Academic Proficiency, the Comprehensive Test of Basic Skills, the New Stanford Achievement Test and the more broadly used Iowa Tests. These assessments are similar in style to those used in Australia and are considered appropriate measures of student educational outcomes within the constraints normally understood for these types of academic achievement assessment programmes.

Structural and Cosmetic Factors Which Influence Learning

Structural factors	Cosmetic factors
Building age	Interior painting
Windows	Exterior painting
Flooring	Interior painting cycle
Heating	Exterior painting cycle
Air-conditioning	Floors swept
Roof leaks	Floors mopped
Adjacent facilities	Graffiti
Locker conditions	Graffiti removal
Ceiling material	Furniture
Science laboratory equipment	School grounds
Science laboratory age	Landscaping
Lighting	
Colour	
Noise	
Student density (m^2/ student)	
Site acreage	

Measuring Student Behaviour

Many of the studies consider student behavioural aspects although this is not easily measured quantitatively. Studies draw on a range of statistical data on behaviour such as vandalism, early school leaving, absenteeism, suspensions, expulsions and disciplinary incidents such as being 'out-of-bounds', violence, disruption in class, lateness, racial incidents and smoking. Flinders University is currently extending the knowledge base on these issues through a number of qualitative research studies in collaboration with selected South Australian schools. The projects seek to provide a deeper understanding of student behaviour through in-depth interviews with individual school students. They provide rich sources of data that may help to explain the precise causes behind the statistical findings on student behaviour.

Overall Building Condition (including Age of the Facilities) and the Relationship to Student Outcomes and Behaviour

Many of the research studies concentrate on evaluating whether a causal link exists between student achievement and behaviour on the one hand, and the overall condition of school buildings on the other. For example, in a study of all of the primary schools in Georgia in the United States, fourth grade students in non-modernised buildings recorded poorer results in basic skills assessment than those in modernised or new buildings.[3] Similarly eighth grade students scored consistently higher (7–8% higher scores) in mathematics, 'composite' and vocabulary assessment if accommodated in new or modernised buildings.[4] This was repeated in a study of 30 elementary schools where teacher attitudes to school buildings were significantly improved in new and modernised buildings. A further study demonstrated an improvement in student achievement scores in newer facilities especially in sixth grade mathematics.

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Seven studies demonstrated that building age is a significant contributor to student achievement and behaviour.[8] In an examination of 280 fourth and sixth grade students in two separate facilities (old and new), those in the newer buildings performed much better than the students in the older buildings, achieving scores over 7% higher. The students in the modern buildings also had a better record in the areas of health, attendance and discipline. The study concluded that approximately 3% of the variance in achievement scores can be explained by the age of the facility after taking into account socio-economic differences in the student populations.[9]

However, there is not total agreement on all of these findings. For example, in one study a strong inverse relationship was found between student behaviour and building age, that is, the older the buildings were, the better the behaviour of the students.[8] It has been speculated that this conflicting finding may be the result of negative student reaction to greater supervision and disciplinary measures in the newer facilities.

It is important to note that, as buildings age, the individual building elements, such as lighting, air-conditioning and floor-coverings, vary in life expectancy and levels of maintenance. Thus different elements will impact on learning and behaviour differentially.

Four recent replicated studies have identified a relationship between cosmetic factors (related to age, maintenance and condition) and student performance and behaviour, with student achievement scores improving by as much as 5% in schools of higher condition ratings.[8] Schools were rated by teachers as *sub-standard*, *standard* or *above standard*.

Another study on student achievement and building condition noted that, as a school moves up from one condition category to another, the achievement scores can improve by over 5%.[10] In the case of a school moving two categories (from poor to excellent in this case study) the student scores improved by more than 10%. Differences, if any, in urban, suburban and rural contexts have not yet been fully analysed.

Individual Building Elements and their Relationship to Student Outcomes and Behaviour

Natural and Artificial Lighting

It is generally accepted that good lighting, both natural and artificial, can contribute to the aesthetic and psychological character of a learning space. Studies confirm that, for fifth and sixth grade students, appropriately designed and well-maintained lighting improves students' achievement scores. Medical studies have shown that natural light is critical to the regulation of the circadian rhythm of the body in adjusting to night and day conditions and therefore of vital importance where students are inside classrooms for much of the day. There is, however, no evidence in the educational literature that this effect has been measured in terms of academic or behavioural outcomes. One educational facilities research organisation recommends that 20% of wall space be allocated to windows located so students can see out from a seated position.[11]

Other findings in the literature on the impact of lighting on students demonstrate:

- the negative effects of poor lighting on students' neuron functions, hyperactivity, health and task behaviour;
- that ultra-violet enhanced broad-spectrum fluorescent lighting can result in better attendance, growth and development; and
- that fluorescent lighting does reduce glare incidence and provides a more diffused spectrum, although it may increase hyper-activity (compared with the use of full spectrum or incandescent lighting).

Colours and their Impact on Students (adapted from Gimbel 1997[12] and Pile 1997[13])

	Activity areas	Passages	Dining areas	Entertainment areas	Study areas	Stress areas	Kitchen areas	Bathroom areas	Offices	Play areas	Entrances	Lecture rooms	
Red	y	y			n	n			n				Alert, increased pulse, activity
Orange	y	y	y	y	n	n							Dance and movement, lightness, joy
Yellow					do not use								Detachment, shallow breathing, mature minds
Green	n				y								Balance, judgement, arrests movement, stasis
Torquoise	n								y	n			Cool, calming, soothing
Blue			n	n					y				Relaxing, sleep inducing
Violet												y	Meditation, dignity
Magenta			n								y	y	Contentment, self respect
Black					do not use								Heightens emotional response
White					do not use								Stark

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Colour

Although no quantitative measures have been identified in the published research, colour is believed to influence student attitudes, behaviours and learning, particularly student attention span and sense of time.[4] It is also believed that carefully planned colour schemes can influence absenteeism, promote positive feelings about the school and, if students like the colours, can also influence muscular tension and motor control. The suggested uses and effects of a range of colours are summarised in the table above.

Air Quality and Temperature

The overwhelming weight of evidence supports a relation between the thermal environment and academic achievement and student behaviour.[5] Temperatures in excess of 25°C have detrimental physiological effects which, in turn, decrease mental efficiency, work outputs and performance. Above this temperature, and with poor humidification, respiration rates are increased, physical efforts become more demanding, attention spans decrease and students report more discomfort. There is also increased absenteeism and conditions favourable to disease and infection spread amongst students. Student achievement is further reduced by poor ventilation, lack of air movement and poor humidity control. Much of the research on this was done before standardised testing was available as a measuring tool. However, students in appropriately controlled environments were observed to make significantly fewer errors on tasks and required less time on tasks than students in uncontrolled environments.[6] In Australia, environmentally sustainable design (ESD) approaches are increasingly being used for thermal control by the Royal Australian Institute of Architects which publishes guidelines for building planners and designers.[7]

Acoustics

The impact of excessive noise in learning settings on learning outcomes has been extensively researched over many decades. Noise emanates from other classrooms, road traffic, trains, aircraft and building mechanical systems. It is clear that inordinate noise levels influence stress, verbal interaction, reading comprehension, blood pressure, cognitive task success, feelings of helplessness, inability to concentrate and lack of extended application to learning tasks.[8] Whilst it was evident that the open-plan classrooms of the 1970s in Australia suffered from noise, more recent designs of large teaching studio spaces use baffling devices to minimise noise transmission. Studies of noise attenuation, particularly the use of carpet with its inherent sound absorbent qualities, have indicated improved student achievement levels although quantitative measurement is not evident in the studies. Background music can enhance reading comprehension and may also be of benefit to students who are below average in achievement and intelligence.[9] Design implications include the increasing use of carpet on floors, acoustic ceiling tiles, softer wall finishes (including artworks), softer upholstery, better sound isolation in and above adjoining walls between classrooms and sound baffles in larger spaces such as lecture and drama auditoria. None of the research studies measured the impact of acoustics on student assessment scores although medical and occupational health, safety and welfare studies have clearly established criteria for acceptable levels of noise in the workplace.[10]

School Size

To date no relationship has been established between school size and student achievement that can be generalised or correlated. However studies do indicate an effect on behaviour. The research seems to indicate that large school sizes may benefit more affluent students but can have an adverse effect on more impoverished students, and vice versa. Some studies show that the negative effect of larger sized schools on the learning outcomes of impoverished students is much stronger than the positive effects of equivalent schools on affluent students.[11] Schools limited to 300–600 students may be as effective in improving student learning as special programmes do although there is some difference in findings across regions.

Furniture

UNESCO's Educational Building and Furniture Programme has been engaged for many years in extensive empirical project based work in developing countries. UNESCO reports that uncomfortable and unsuitable furniture causes problems including backache, poor concentration spans and writing difficulties, thus reducing learning opportunities.[12] There is a general body of work on ergonomics that support these conclusions. These fundamental principles are clearly also applicable to the developed world, although it appears that no specific research studies have attempted to measure the impact.

Design Factors which can influence Learning Outcomes and Behaviour

The Educational Specification

More recent empirical research explores how spaces should be re-configured to assure improved student behaviour and outcomes. Many building projects evolve from revisions in pedagogy and curriculum and new trends in behavioural research. For example, a 1993 Australian Government report identified the need for a separate environment for middle schooling.[13] Whilst the middle school might still be collocated with the senior school to enable the sharing of specialist facilities, separation allows 11 to 16 year olds (in years 8 to 10) to have an identity, focus and culture of their own, independent of the influence of older students in years 11 and 12. There is also an increasing need for flexibility (such as movable furniture) during class sessions, as well as the eventual removal of adjoining classroom walls, to create larger spaces for new pedagogical approaches. Research is yet to determine whether these flexible spaces will improve student behaviour and outcomes. However, the uncertain future regarding the impact of technology on pedagogy and, inevitably, on student outcomes, is implicit in these studies.

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Learning Settings

There is some evidence to support links between the levels of privacy of a learning setting and the behavioural characteristics of students, particularly in libraries. Behaviour is seen to be dependent on the potential for exposure to visual monitoring of one's behaviour by others. For example, traditional classroom designs with students at the back corners exclude those students from interactive proceedings at the front, with consequent disruptive or inattentive behavioural patterns.[5] Research in Australia has shown that these traditional classroom designs are less than optimal for the delivery of the new primary school curriculum, unless the classroom space allocation is increased to allow for additional technology and wet and dry practical areas.[6] However, no 'scientifically rigorous' research studies were identified which attempt to measure links between the design of learning settings and student achievement and behaviour.

Other Factors

A range of other building design factors and elements are currently under investigation to determine possible relationships between these factors and student behaviour and academic outcomes. The factors include the amount of space allocated per student, the openness of space, the use of underground or windowless facilities, site size, building utilisation and room occupancy rates, the range of support facilities (including storage) and the availability of specialist instructional facilities. The replication, validity and reliability of the research methodologies and 'scientific' rigor in these studies is still evolving.

Studies on science laboratories indicate strong causal links between the quality and amount of science equipment and furniture design on the one hand and the quality of student behaviour and learning outcomes on the other. A difference of 7% in science scores occurred between schools rated low and high in overall science facility quality. Libraries have recently been undergoing extensive design remodelling and rethinking to accommodate the increasing use of Internet access, multi-media and other new technologies. Student behaviour appears to be particularly sensitive in libraries, as students work independently outside formal classrooms on individual project and problem-based curriculum requirements or on group projects.[7]

European studies confirm that the aesthetic appearance of a school can convey subtle messages that act as perceptual constraining factors for both staff and students. School architecture can facilitate the transmission of cultural values, stimulate or subdue, aid in creativity, slow mental perception and cause fear and joy.[8] The emergence of new understandings of contextually and socially based cognition is

Socio-spatial Factors in School Design

	Formal Learning Settings	Informal Learning Settings (inc. community use & public spaces)
Outdoor Spaces	• Outdoor classrooms • Learning through landscapes • Social interaction • Security gradients	• Social interaction • Territoriality • Gathering • Surveillance • Out of bounds • Safety • Promenade • Green areas • Play areas • Quiet areas • Entrance area • Private spaces • Hard and soft landscaping
Indoor Spaces	• Crowding • Spaciousness • Social interaction • Personalisation and ownership • Building functionality • Safety and security • Clusters / instructional neighbourhoods • Compact • Flexible / adaptable • Diversity and variety of settings • Activity pockets and learning zones • Location of administration / teacher offices • Controlled climate / acoustics / lighting • Storage • Ceiling heights	• Community centre / use • Diversity and variety • Public areas • Technology for teachers and students

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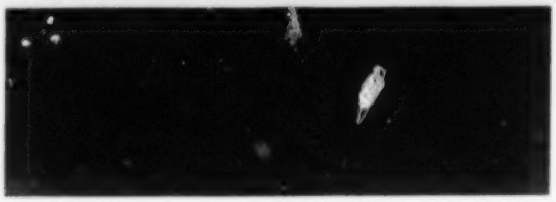

shaping this research. A six-year study at the University of Goettingen determined that student perceptions of, and behaviour in, learning environments are influenced by the scale of the buildings and the variety and stimulating potential of structural shapes and colour schemes.[26] These patterns were measured qualitatively and statistical results are therefore not available. Studies of eye movements, as students viewed their learning environment, saw them compensating for angular designs resulting in a degree of discomfort and imbalance which, in turn, affected their concentration span and reduced their 'time-on-task'.

Other factors impacting on students include transitional spaces (indoor / outdoor), the anthropological and social aspects of design, sensory stimulation, context, schools-within-schools, harmony, the incidence of views and vistas, functional zones, circulation patterns and supervisable circulation spaces (such as hallways and corridors). These and other factors are under investigation by researchers who have proposed a range of new conceptual approaches to the design of learning environments as listed in the table on socio-spatial factors in school design.[27] These theories are yet to be subjected to rigorous research to measure the impact, if any, of these factors on student behaviour and academic achievement.

Final Note

This review suggests that most of what is known about the relationship of school infrastructure to student behaviour and learning outcomes pertains to general conditions and aspects such as lighting, acoustics and temperature control. To the extent that impact on behaviour and outcomes is taken into account in designing school buildings, it is largely theoretical rather than proven relationships which influence design trends and specifications. This is not to say that the solutions adopted have not been correct. It is clear, however, that further research into the contribution of design factors to student behaviour and outcomes may assist architects, educators and policy makers to better understand the real impact of investment in school infrastructure.

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Useful websites and endnotes

http://www.deetya.gov.au/edu/school_index.htm
http://www.edfacilities.org/ir/assessment.html
http://www.ltl.org.uk/index.html
http://www.hudson.acad.umn.edu/surprises/home.html
http://www.designshare.com.html
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